Anatomy of a Proposed Sewage Treatment Scheme in an Urban Setting: A Case Study

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Abstract: Construction of sewage treatment plants (STPs) is not a simple solution to the issues of eutrophication and algal blooms being faced by rivers in the developing countries. In the present work, the sewage treatment scheme of an urban city in India has been studied and projections for the sewage generation in future have been made and compared with the earlier provided estimates. Their efficiencies have been evaluated on a monthly basis for water quality parameters such as BOD_5, TSS and COD. The current study, has also estimated the costs (considering the inflation rate) to fulfil the treatment requirements of future on a medium term (target 2025) and long term (target 2040) basis.

1. INTRODUCTION

Sewage, also called as waste water, is any water that has been negatively affected in quality due to human interferences. It is the collective form of liquid waste from domestic establishments, commercial areas, industrial areas, and agricultural runoffs and also includes several potential contaminants and substances which are otherwise harmless but are hazardous in high concentrations. Commonly, sewage refers to the municipal waste that drains out of establishments and drains into the river and contains major contaminants from the mixing of sewage from different sources. Municipal sewage is conventionally treated in a combined sewer line, sanitary sewer or septic tank. Due to the excessive discharge of sewage into the water bodies they are not able to employ their self-purification capacity, hence the dissolved oxygen level in the water body reduces this leads to disappearance of aquatic flora and fauna and often mass death of the fishes. Therefore, the treatment of sewage becomes a necessity as it drains into the rivers and rivers are the main source of fulfilling the needs of fresh water by humans. Sewage treatment systems are very necessary due to the following reasons-

- To promote public health and decrease the risk of diseases.
- To eliminate the net effect of pollution on water bodies.
- To reach the water quality standards that allow aquatic organisms and plants to flourish.
- To attain water quality good enough to allow human recreational use.
- Removal of organic contaminants including bacteria from the water.
- Addition of strong oxidants like Chlorine in order to remove residual bacteria in sewage that has been separated [1, 8].

2. METHODOLOGY

2.1 Sewage treatment in study area

The difference in the lifestyles and population growth patterns in developing and developed countries is responsible for the differences in measures required for water pollution control and treatment. Use of faulty material in construction, low operation and maintenance, encroachments, etc. are responsible for difference in estimated wastewater generation and the real condition. This study makes a similar comparison for the study area.

Lucknow city, the capital of the state of Uttar Pradesh state in India has been selected as the study area. The laying down of sewer lines in Lucknow city to direct the sewage generated by the whole city was proposed under Jawaharlal Nehru Urban Renewal Mission (JNNURM). The scheme aimed at directing the entire sewage generated in the city to the 2 STPs currently functioning in Daulaganj and Bharwara areas. The overall sewerage scheme Lucknow has been divided into 4 sewerage districts as in figure 1 [4].

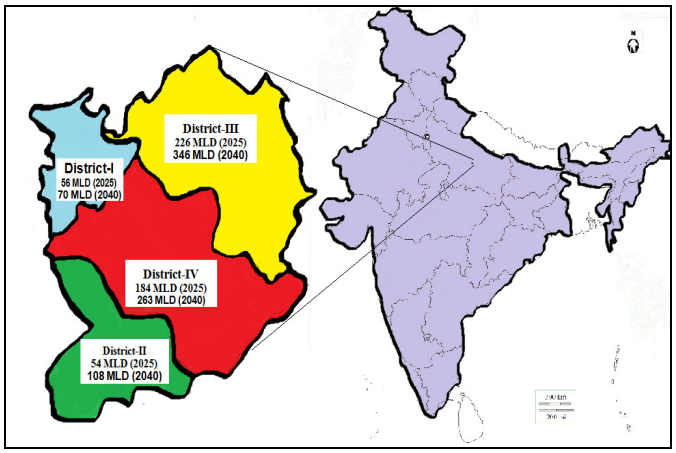

Fig. 1. Different sewerage districts in study area- Lucknow

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2.2 Current and proposed status of sewage treatment facilities

The STP at Daulatganj was approved at an estimated cost of Rs.58.11 crore in April 1993 and started functioning from 2002 based on Fluidised Aerobic Bed technology with a capacity of 42+14 MLD. It treats the waste water of Nagaria Nala, Gaughat Nala, Sarkata Nala and Pata Nala which are located very close to Gaughat raw water intake. Table 1 shows the distribution of sewage treatment capacities in the 4 sewerage districts.

Table 1- Distribution of sewage treatment capacities in the 4 sewerage districts

District No.	2010 (proposed/ actual capacity of STPs in MLD)	2025 (proposed capacity of STPs in MLD)	2040 (proposed capacity of STPs in MLD)
I	56/(42+14)	56	70 (56+14)
II	-	54	108 (54+54)
III	-/345	226/345	345
IV	-	184	263 (184+79)
Total	56/401	520/639	786

The second phase works of GoAP amounting to Rs. 263.04 crore were launched in 2003. UASB based sewage treatment plant of capacity of 345 mld which started functioning from January 2011 was commissioned under the same. It was constructed to divert the sewage from the remaining parts of the city via the G H Canal and Kukrail Nala which in turn received sewage from other smaller drains. Though these 2 STPs should be just sufficient to cater the current demand of sewage treatment but at times they receive overload and it is expected that after complete sewerage connections are done they will together not be sufficient to meet the demand. At the same time it has also been perceived that though the work of linking these drains started at a great pace under JNNURM but with time the enthusiasm died away and this scheme has currently been over shadowed but bigger schemes like Metro Rail and IT Park.

2.3 Sample Collection

The monthly averages BOD, COD and TSS loads (mg/l) in the inflow and outflow of the two existing STPs, at Daulatganj and Bharwara in Lucknow city has been collected for a period of 1 year and the average values have been compared for removal efficiencies for three water quality parameters- Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS). These results have been evaluated in terms of % removal / reduction and the results have also been shown graphically.

Further, the population of Lucknow has been reported to grow in an exponential manner considering the fact that the city is growing both horizontally and vertically in a rapid manner. Hence, the population and sewage generation of the city has been projected for a medium term (2025) and a long term (2040). The sewage treatment capacity required in the medium term (2025) and long term (2040) future has been evaluated and compared with the requirements proposed in the Master Plan of Lucknow city. Further the cost incurred in increasing the capacity of capacity beyond the Master Plan and the expected revenue generation has been calculated.

3. RESULTS AND DISCUSSION

3.1 Efficiency of the existing sewage treatment plants

The yearly average values of the water quality parameters namely; BOD, COD and TSS have been evaluated for the two STPs at Daulatganj and Bharwara in Lucknow city, based on FAB (Fluidized Aerobic Bed) and UASB (Upflow Anaerobic Sludge Blanket) technologies respectively [3]. Table 2 shows the values of these water quality parameters and their reduction percentage after undergoing treatment in both STPs. The treatment in both STPs is aerobic and anaerobic in nature respectively.

Table 2: Treatment Characteristics of treatment plants under study

Water quality parameter	FAB STP			UASB STP		
	In	Out	% Change	In	Out	% Change
BOD	111	24	78	92	22	76
COD	213	52	76	200	49	76
TSS	237	24	90	213	23	89

Considering the above values of BOD, COD and TSS for the 2 STPs, the percentage efficiencies of both STPs for these particular parameters are shown in graphical form in following figures 2-4.

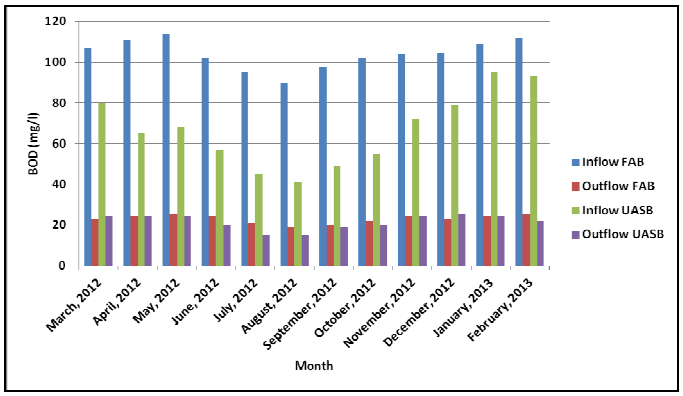

Fig. 2. BOD levels in the STPs

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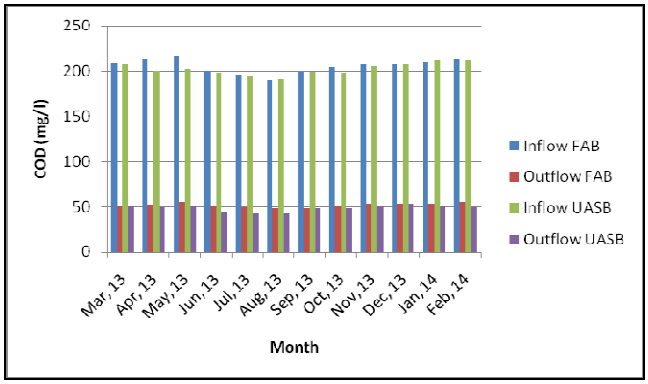

Figure 3- COD levels in the STPs

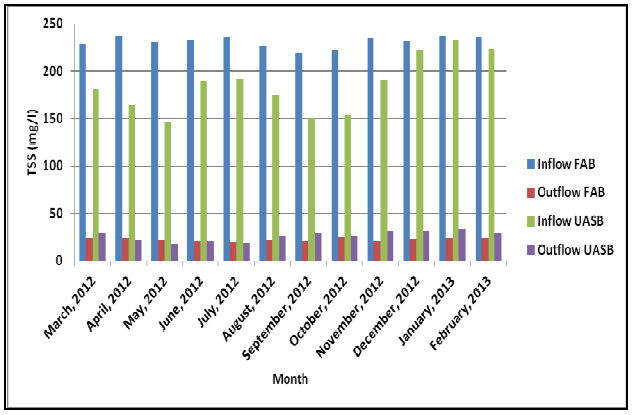

Figure 4- TSS levels in STPs

3.2 Population projection

Due to good living conditions and supply of electricity, the population rise is very fast both in vertical and horizontal directions, hence the Semi-log method will best project the population of Lucknow in near future as shown in figure-5 and table-3.

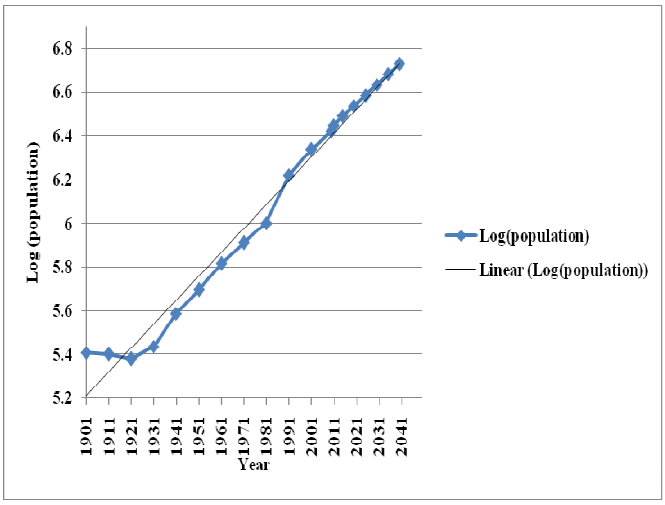

Fig. 5. Population projection of Lucknow by semi-log method [5]

Table 3- Predicted population as per semi-log method

Year	Predicted Population
2010	2644235
2015	3101702
2020	3460190
2025	3860113
2030	4306258
2035	4803967
2040	5359200

Based on the above predicted population, wastewater generation in past, immediate future and long term and hence the proposed capacity of sewage treatment plant required has been has been calculated and shown in Table-4 considering 1.20 as the peak factor and 135 lpcd (Litres per capita per day) as the quantity of water supply [7].

Table 4: Wastewater generation prediction as per semi-log method

Waste Water Generation / Proposed Capacity of STP in MLD		
Base Year 2010	Middle Year 2025	Design Year 2040
(2644235x135 x 1.20)/ 10^6	(3860113x135 x 1.20) / 10^6	(5359200x135 x 1.20)/ 10^6
428.37	**625.34**	**868.19**

4. CONCLUSIONS

4.1 Additional sewage treatment requirements

Currently, the available capacity of STPs is deficit from the actual requirement by (428.37-401) = 27.37MLD. For District III a plant of capacity 226 MLD was proposed for 2025 but a fully functioning plant of 345 MLD was commissioned in 2011. According to the calculated value of waste water generated, by 2025; another STP of additional capacity of (625.34-401) = 224.34 MLD will be needed. Two new STPs in District II (54 MLD) and IV (184 MLD) have already been proposed. Their construction will sum up to a total capacity of 639 MLD (4 STPs) for the entire city whereas the actual need will be approximately 625.34 MLD i.e. the requirement will be fulfilled by the proposed construction. By 2040, it has been proposed to increase the capacity of the 4 STPs such that it will sum up to a total capacity of 786 MLD, whereas the actual requirement will be more than 868.19 MLD, i.e. an additional requirement of (868.19 - 786) = 82.19 MLD will be there. Besides, the current inflow is highly diluted in nature so measures should be taken to concentrate it so as that the STPs can function to full capacity and it will also aid in resource generation.

It is suggested that due to the current requirement of 27.37 MLD, the capacity of the 345 MLD STP in District III should be increased. At the same time this STP will also fulfill the

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additional need in 2025, after the construction of the proposed STPs in District II and IV. At the same time, by 2040 the capacity of UASB plant in district III should further be increased by 82.19 MLD. The capacity of UASB plant is increased in both the cases as the land acquired for the UASB plant is 650 acres and it is currently constructed on only 120 acres. The cost of increasing capacity of the UASB plant by 53.1 MLD by 2025 and by 201.18 MLD by 2040 has been shown in table 4.9, and the cost has also been estimated considering inflation rate of 6.0% per annum using the following formula [2, 6]-

$$\mathbf{CV = RV \times (1 + i)^n}$$

where;
CV = Current value or nominal value of rupee
RV = Real or purchasing value of rupee
n = Time period (in years)
i = Average inflation rate per annum [16]

Table 5 that follows provides a detailed description of the additional sewage treatment capacities required by 20125 and 2040, costs incurred in their construction and further costs incurred in 2025 and 2040 considering inflation.

Table 5- Cost incurred by additional STP facilities

Description	Unit	Bharwara STP (345 MLD) in 2010	Additional production by 2025	With inflation rate of 6.0% p.a.)	Additional production by 2040	With inflation rate of 6.0% p.a.)
Sludge produced	TPD	40	3.17	-	9.53	-
Revenue from sale of sludge	Rs. Lakh	18.00	1.43	3.43	4.3	24.7
Biogas generation	m^3/h	Insufficient	Cannot be predicted	Cannot be predicted	Cannot be predicted	Cannot be predicted

4.2 Revenue generation from the extended capacity of the UASB plant

The UASB plant is currently spread across an area of 120 acres with a capacity of 345 MLD. The land available for its future extension is 650 acres so as per the increasing requirements the capacity of this plant can be extended without the requirement of land acquisition. Though presently the sewage received is highly diluted and low in BOD so the biogas generation is insufficient currently.

The table 6 that follows provides the estimated costs for revenue generation in case of the extended UASB capacity. It also provides information about the costs incurred in 2025 and 2040 considering the inflation rate of 6 % p. a.

Table 6 - Revenue generation in case of the extended UASB capacity

Description	Unit	Bharwara STP (345 MLD) in 2010	Additional need by 2025	With inflation rate of 6.0% p.a.)	Additional need by 2040	With inflation rate of 6.0% p.a.)
Technology	-	UASB	UASB	UASB	UASB	UASB
Capacity	MLD	345	27.37	27.37	82.19	82.19
Construction cost (exc. land)	Rs. Lakhs	16971.00	1346.37	3226.65	4043.03	23221.11
Annual Power Cost	Rs. Lakhs	222.65	17.66	42.32	53.04	304.63
Net annual O/M Cost	Rs. Lakhs	599.19	47.54	113.93	142.75	819.88
TOTAL	Rs. Lakhs	17792.84	1411.57	3382.91	4238.82	24345.63

5. ACKNOWLEDGEMENT

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